Linder.

A Study Of Electrical Lubrication.

A STUDY OF ELECTRICAL LUBRICATION

BY

SVEN CYRIL LINDER

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Sven Cyril Linder

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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Ceramics

R. K. Hursh
Instructor in Charge

APPROVED: R. K. Hursh

HEAD OF DEPARTMENT OF Ceramic Engineering

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ELECTRICAL DIE LUBRICATION

I General Introduction

There are three important factors in the successful and economic production of clay-products, viz., the forming, the drying, and the burning of the product. The failure of the clay to behave satisfactorily during any one of these stages of manufacture will eliminate it from the field of workable clays. Obviously the first factor is the most important.

In the stiff-mud process of forming clay wares there is always present the defect of lamination, which may or may not be strongly enough developed to seriously injure the quality of the product. Due to the principles of operation of the machines now used in this process a laminated structure is always produced which may be destroyed by the introduction of certain mechanical devices.

This defect of lamination has been found to be of two kinds, commonly known as auger lamination and differential lamination. Prof. Stull[1] describes auger lamination thus, " The streams or strands of clay are delivered from the auger wings in helical form, and in this condition the clay is forced into the die. The strands of clay are imperfectly welded as the clay passes through the die, thus giving a structure similar to the twisted strands of a rope." In explaining differential lamination he says, " On account of the friction of the clay against the iron with which it is in contact the clay flows at a greater speed at the center of its stream, resulting in a structure resembling overlapping cones, giving what is called a differential laminated structure."

There are various ways of reducing the effect of auger lamination, such as, the use of cross bars, knives, or revolving blades, placed in front of the auger, or by installing double-wing augers instead of the common single-wing.

In order to reduce differential lamination there seems

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1 Points on the Construction and Operation of the Lubricated Die. by R.T.Stull, Proceedings of the 26th Annual Convention of the National Brick Manufacturers Association.

to be but one method of proceedure, which is, the introduction of proper lubrication between the die and the clay column. A change in the design of the die will often materially help. With correct lubrication the clay column will move through the die with practically equal velocity at all points of its cross-section. The construction of scales in the die makes it possible to force any lubrication medium out between the surface of the clay and the die. Water, steam, oil, and soap-solutions are used as lubricants, each according to the best results obtained on the particular clay involved. Thus, in this feature of die lubrication alone, the clay worker has quite a problem to solve satisfactorily for each individual clay. Of the several means of lubrication now practised no single one can be claimed to have universal application, and each one has its own individual peculiarities in requirements for operation.

II Electrical Die Lubrication

With a view of overcoming the difficulties incident to lubrication there was presented on the market, a few years ago, an electrical process for lubricating brick dies. A great deal of time and money had been spent toward perfecting the process and valuable results were offered by its use, yet its general adoption has, for some reason, been detered. Whether this is due to the notorious skepticism of the clay working fraternity or the failure on the part of the process to fulfill promises can not be said definitely. However, a brief examination of the principles of the new process shows it to be very promising.

Theory of the Electrical Process

If small particles are in suspension between two electrodes they will migrate under the influence of a direct current either to the cathode or the anode, this phenomenon being known as kataphoresis.[2] The suspended particles will

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[2] Technological Paper of the Bureau of Standards, No.51

migrate to the positive or negative pole according to the negative or positive character of their charge. Thus clay, quartz, sulphur, etc. will travel to the positive electrode, while water will pass to the negative pole. According to Bleininger[3] the plastic state of clay might be considered as a special case of clay in suspension, in which the particles approach each other so closely that cohesive forces come into play. By applying these considerations to the case of the plastic column of clay as emitted in the stiff-mud process of manufacture, we can conceive of a direct current drawing water out of the column at the negative pole. Then it is but a step to place the negative pole on the die and the positive pole on the barrel of the brick machine, insulating the two from each other. Thus the positively charged water in the clay column is drawn to the negatively charged die and, collecting on the surface of the column between it and the die scales, forms the lubricating medium. The conditions are

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[3] The Effect of Electrolytes Upon Clay in the Plastic State. A.V.Bleininger, Vol. 5, Eighth International Congress of Applied Chemistry.

further favorable toward reduction of friction since the negatively charged clay is repelled by the negatively charged die surface. This, in brief, is the principle on which electrical die lubrication operates.

III Object of the Investigation

Using the principle of the electrical process of die lubrication a series of experiments were conducted with a view of determining (1) the lubricating value, (2) the results of varying the water content, (3) the effect on the velocity of the issuing clay column, and (4) the adaptability of different clays.

(1) In determining the lubricating value of a medium the only criterion, as now practised, is the appearance of the corners and the surfaces of the clay as it issues from the mouth of the die. If there is no tearing of the surface and no ruffling of the corners and the whole comes out smoothly then the lubrication is considered perfect. This criterion was, then, necessarily the one followed in the experiments conducted.

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(2) Every brick plant finds that there is a certain amount of water to be used in pugging up their particular clay in order to get the best results. Some clays require less water than others, and this feature of varying water content will affect the amount of current needed for the electrical process. Thus it will be of value to know just how the current varies with different water contents and where the best results are obtained.

(3) In changing the water content of a clay fed into the auger machine it is obvious that the velocity of the clay column as it is expressed from the die will also change. In connection with this it may be assumed that for a constant water content the velocity of the clay column will increase with increase of voltage since an increase of voltage means more water migrating to the die surface to lubricate. In the present experiment it was therefore thought advisable to collect data on the relation between voltage, velocity, and water content.

(4) As was mentioned in the general introduction, different clays require different lubricating media. Some clays, owing to their nature, require but little water in pugging, but need strong lubrication, and vice

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versa. Thus it was thought necessary to experiment with different types of clays to determine the adaptability of the electrical process to any clay.

IV Construction of the Apparatus

All the clays were pugged in a wet pan, the desired water content being approximately determined by the feel of the pugged mass.

A small auger machine of the type manufactured by the Mueller Company for testing purposes, was used for shaping the clay. The essential dimensions will be noted in fig. 1. The insulating material first used was gasket rubber, but later thin fibre was adopted because of its greater strength and convenience in handling. Varnished cambric, known as Empire Cloth, was used for insulating the bolts.

The direct current required was obtained from a ½ H.P. shunt-wound D.C. generator run by a 2 H.P. single phase A.C. induction motor of constant speed. The motor was connected to a 110 A.C. main. The set-up of the apparatus is shown in fig. 2. The water rheostat was introduced as a rough means

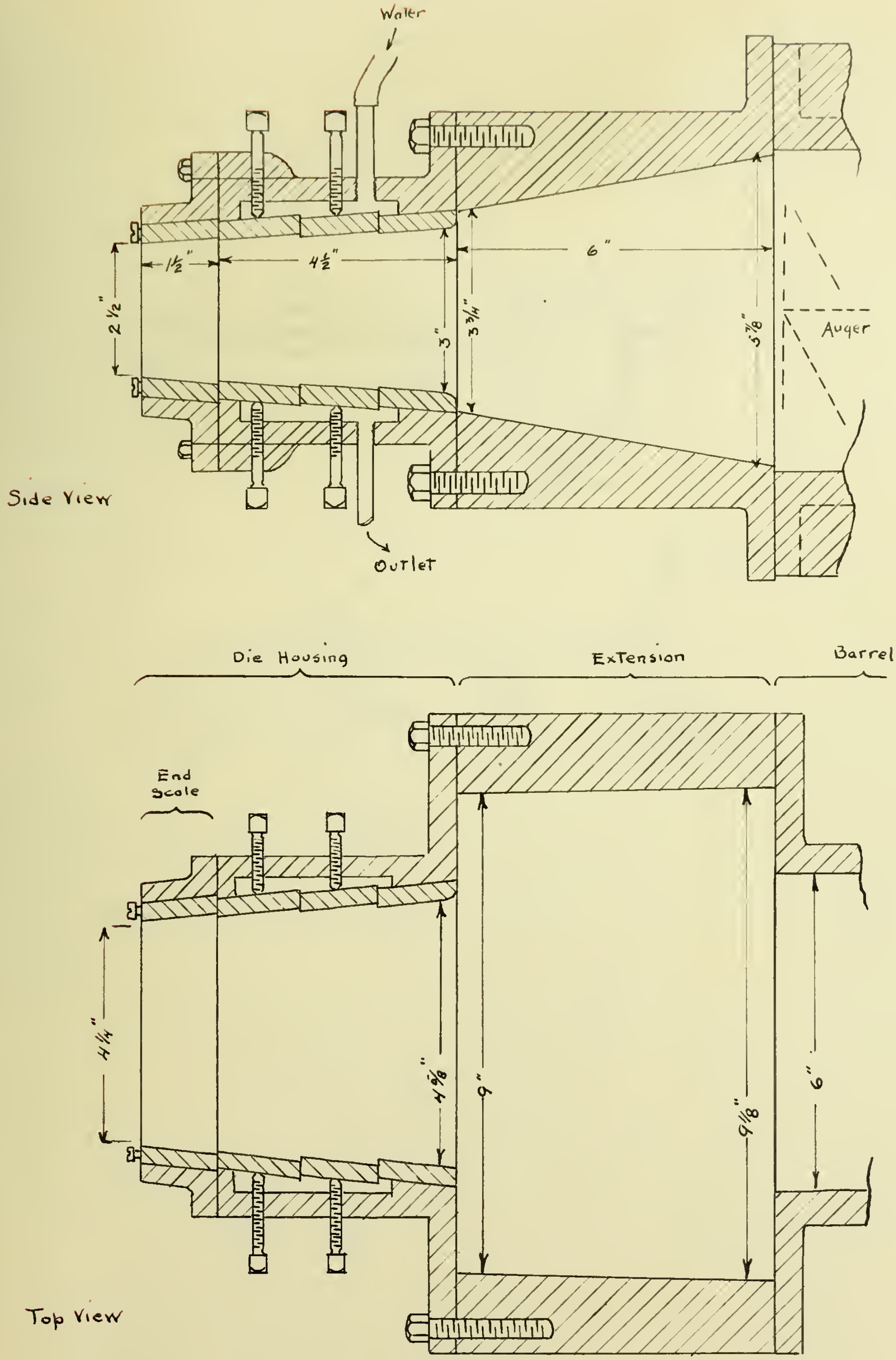

Fig. 1   Scale 1" = 3"

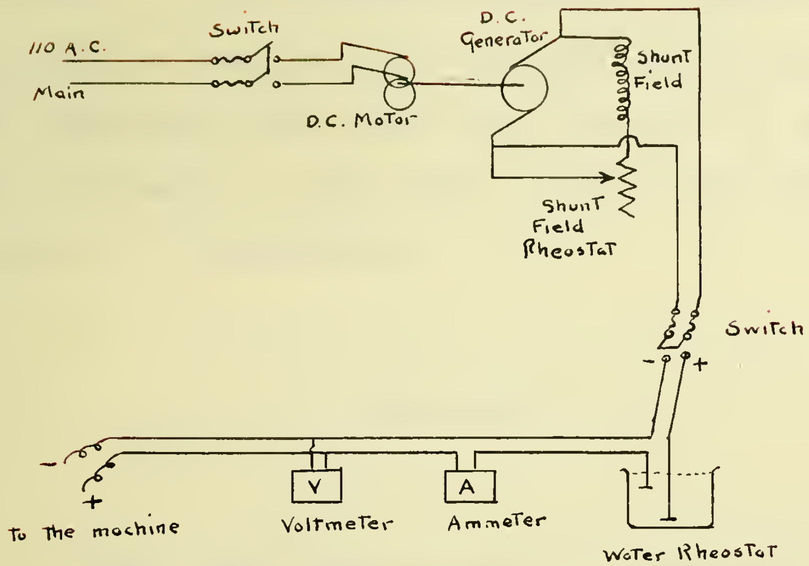
110 A.C.
Main
Switch
D.C. Motor
D.C. Generator
Shunt Field
Shunt Field Rheostat
Switch
-
+
-
+
To the machine
V
Voltmeter
A
Ammeter
Water Rheostat

Fig. 2

of regulating high voltages and also to act as a safety device to prevent any over-load on the generator in case of short-circuiting. The voltage generated was regulated by the shunt field rheostat.

At first it was thought that merely winding the wires around bolts on the die and the extension would provide sufficient connection, but after the first test it was found to be more successful to have heavy copper wire screwed fast to the surfaces of the machine.

V Clays Used

Three clays were selected to represent the three types most commonly used in the stiff-mud process of manufacture. They were, a shale from Streator, Illinois, a No.2 fire-clay from Bloomingdale, Indiana, and a surface clay from Urbana, Illinois.

The Streator shale was rather short, but worked well in a die, and is used in the manufacture of paving brick. The Bloomingdale fire-clay was of the stoneware type often used for face-brick, and the Urbana surface clay was of a short, sandy , but very sticky kind utilized in soft-mud machines.

VI Out-line of Work

The experiments were carried out according to the following method of proceedure:

(1) Each clay was pugged in the wet pan into three batches of distinctly different water content. One batch was of the proper consistency for stiff-mud manufacture as maintained on the plant, one had an excess of water, and the third had a deficiency.

(2) Each batch was then run through the auger machine with constant rate of feeding, the auger maintaining in almost all cases a constant speed of revolution.

(3) As each clay passed through the die it was subjected to varying voltages. The voltage drop through the die and the corresponding amperage were recorded in each case.

(4) The velocity of the issuing clay column was taken for each change of voltage through the die. In each case a point on the clay column two feet from the mouth of the die and having two feet of column ahead of it was timed in seconds over a distance of one foot.

(5) For each voltage two samples were cut from the column, for the determination of the exact water content. These

samples were weighed wet, dried in the open for one day, and then put in a steam drier till perfectly dry when they were weighed again. The water content was calculated according to the formula:

$$\frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100 = \% \text{ water content.}$$

VII Results

Preparatory Tests

The preparatory tests were made on the shale pugged to normal plasticity in the wet pan.

With a view of discovering the best methods of insulating and wiring the die, the tests were made with the following arrangements :

(1) The die and the extension were insulated from the barrel, and the negative wire was attached to the die with the positive wire attached to the barrel. See fig. 3.

(2) The die-housing was insulated from the extension with the wires attached as before. See fig. 4.

(3) With the negative wire on the die-housing as before, the positive wire was attached to the extension. See fig. 5.

(4) The end scale of the die was insulated from the rest of the die-housing, and to one corner of this scale was fastened the negative wire, the positive wire remaining on the extension as before. See fig. 6.

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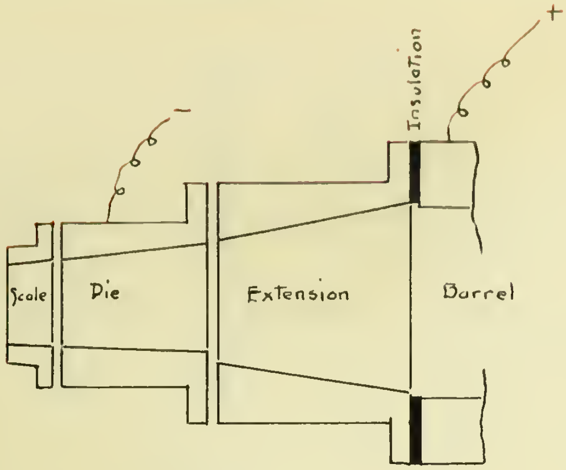

Fig. 3

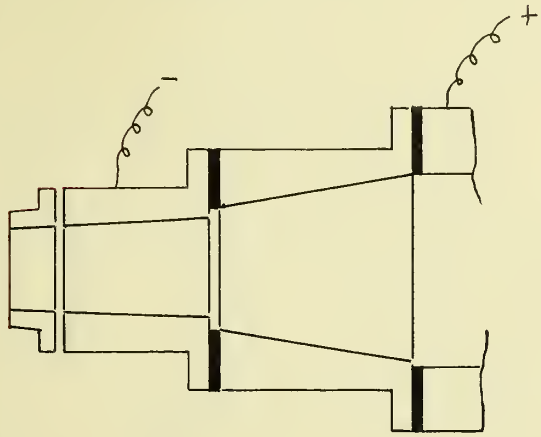

Fig. 4

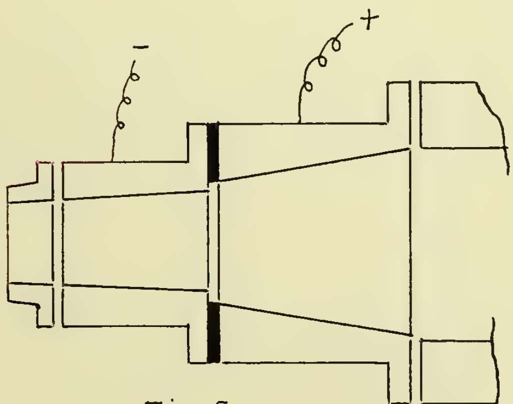

Fig. 5

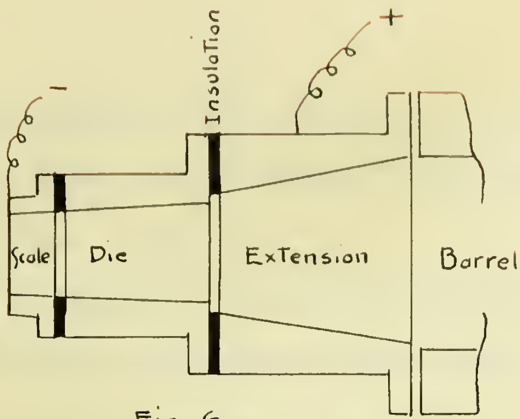

Fig. 6

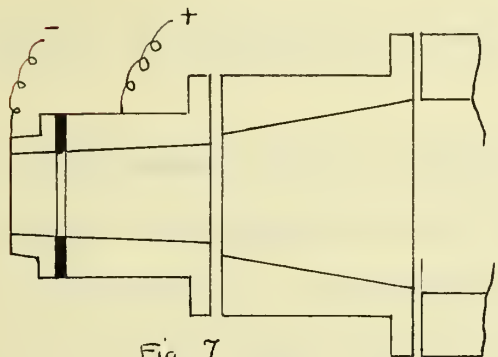

Fig. 7

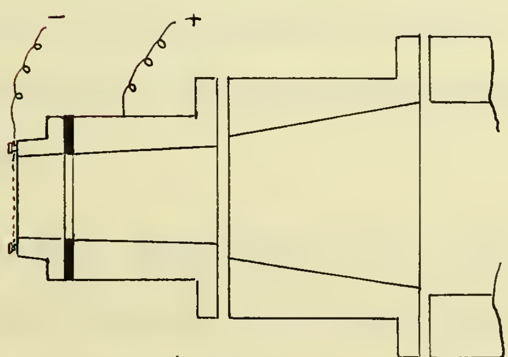

Fig. 8.

(5) The negative wire was kept as in (4) and the positive wire was attached to the remainder of the die-housing. See fig. 7.

(6) The wiring was kept as in (5) except that the negative wire was screwed down fast all around the face of the end scale. See fig. 8.

Results of Preparatory Tests

(1) This arrangement proved entirely unsatisfactory as no lubrication could be obtained at the die. The current proved effective in bringing out the water just beyond the point of insulation, but its range did not extend to the die.

(2) The voltage of the generator could not be raised sufficiently to give any lubrication values. This was due to the resistance offered by the insulated extension lying between the two poles.

(3) With this arrangement the first fair indications of lubrication were obtained, but even these were far from satisfactory. The current showed in all cases, a tendency to confine its action to those parts just beyond the insulation, on the negative side. Thus it was found that the part of the

die nearest the insulation was within the lubricating area, but that the end scale was not within the effective range.

(4) Here, again, high voltage was required, due to the insulated length of the die. Good results were noted at the high voltages, but a new defect became apparent. With increasing voltages the corner to which the negative wire was fastened gave the best results, while the diagonally opposite corner of the scale was somewhat worse.

(5) This arrangement proved entirely satisfactory with the exception that the corner of the scale with the wire attached was the first to respond to changes in the current and always gave slightly better results than the other three.

(6) This was the arrangement finally decided upon, as here the least voltage was required and the best and most uniform lubrication was obtained.

Streator Shale -A-

Volt.	Amp.	Watts	Vel. sec/foot	% water	Remarks
0	0	0	27.0	22.25	Corners very ragged, surface fair.
9.5	.25	2.37	24.0	23.61	Corners slightly torn, surface good.
18.25	.30	5.48	22.0	21.69	Corners fair, Surface good.
37.00	.60	22.20	23.0	21.95	Corners fair, surface good.
55.0	.85	46.75	24.0	21.80	Corners fair, surface good.
63.0	1.10	69.30	24.0	22.10	Corners fair, surface good.
69.0	1.15	79.35	22.0	21.60	Corners good, surface good.
72.5	1.17	85.18	24.0	21.75	Corners fair, surface perfect.
77.0	1.30	100.10	24.0	22.30	Corners fair, surface perfect.
80.0	1.46	116.80	22.5	21.65	Corners fair, surface perfect.
90.75	1.46	133.00	24.0	21.18	Corners good, surface perfect.
95.00	1.50	142.00	23.5	20.70	Corners perfect, surface perfect.
101.0	1.57	158.57	23.0	21.35	Corners good, surface perfect
105.0	1.67	175.35	23.0	21.20	Slight ruffling, surface perfect.
109.5	1.75	191.62	24.0	20.80	Slight ruffling, surface good.
114.0	1.90	216.60	26.0	20.05	Slight ruffling, striations appear.
127.0	2.05	260.35	27.5	21.85	Slight ruffling, More striations.
159.0	2.60	413.40	25.0	21.81	Slight ruffling, striations worse.
				21.65	

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Results

Streator Shale -A-

The shale was pugged to a normal plasticity in a wet pan, the water content averaging 21.65%.

No current-	Under these conditions the die was dry and the clay column issued with the corners badly ruffled and the surface slightly rough.
9.5 to 80. volts-	The column showed immediate reduction of ruffling upon passage of current. With increase of voltage the corner ruffling gradually decreased and surface got smoother.
90. to 105 volts-	Between these limits the column was practically perfect.
110 to 160 volts-	Increasing the voltage caused a very gradual increase of corner ruffling while small, wavy striations, like flattened ruffles appeared on the surface. These effects are similar to those obtained when using excess pressure in water or steam lubrication.
Water lubrication-	At 5 pounds water pressure a perfect column issued at the rate of 24 seconds to the foot.

Streator Shale -B-

Volt	Amp.	Watts	Vel. sec/foot	% water	Remarks
0	0	0	33.0	17.95	Corners very ragged, surface fair.
40	.60	24.	28.0	18.73	Corners quite rag'd, surface fair.
50	.80	40.	27.0	19.20	Corners less ragged, surface good.
60	1.00	60.	28.0	18.64	Corners slightly torn, surface good.
70	1.15	80.5	26.5	18.62	Corners slightly torn, surface good.
90	1.55	139.5	27.0	17.95	Corners good, surface perfect.
100	1.86	186.0	28.0	17.96	Corners good, surface perfect.
110	1.88	206.8	28.0	17.79	Corners good, surface perfect.
120	2.15	258.0	29.0	17.97	Corners perfect, surface perfect
130	2.40	312.0	28.0	17.75	Corners good, Striations appear.
				18.19	

Streator Shale -B-

Sample B was pugged with a deficiency of water, the water content amounting to only 18.19 % as an average.

No current-	A very ragged column with a low velocity resulted.
40 to 100 volts-	Increasing the voltage gradually reduced the tearing of the corners, while the surface very quickly became smooth. A slight increase of velocity was also obtained.
100 to 130 volts-	Between these limits a practically perfect column was obtained. However, at the highest voltage surface striations began to appear, indicating an excess of lubrication. No definite change of velocity was noted

Streator Shale -C-

Volts	Amp.	Watts	Vel. sec/foot	% water	Remarks
0.	0.	0.	35.0	23.35	Corners ragged, surface poor.
19	.35	6.65	24.0	23.41	corners bad, surface fair.
35	.60	21.00	23.0	22.99	Corners slightly torn, surface good.
74	1.15	85.10	24.0	23.20	Corners slightly torn, surface good.
90	1.50	135.00	27.0	24.51	Corners good, surface perfect.
108	1.70	183.60			Slight welding, striae appear.
126	2.00	252.00			More welding, striations worse.
145	2.40	348.00			Welding bad, striations very bad.
				23.59	

Streator Shale -C-

An excess of water was used in pugging this sample, giving an average water content of 23.59 %.

No current-	An extremely ragged column resulted, issuing at a comparatively low velocity.
19 to 75 volts-	The lubricating effect improved very rapidly with increasing voltages. An immediate marked increase of velocity was noted.
75 to 95 volts-	These were apparently the limits of practically perfect results. The velocity showed no increase.
95 to 145 volts-	The effects of excess lubrication were but faintly noted in the way of welding of the corners, and slight striations. The velocity remained practically the same.

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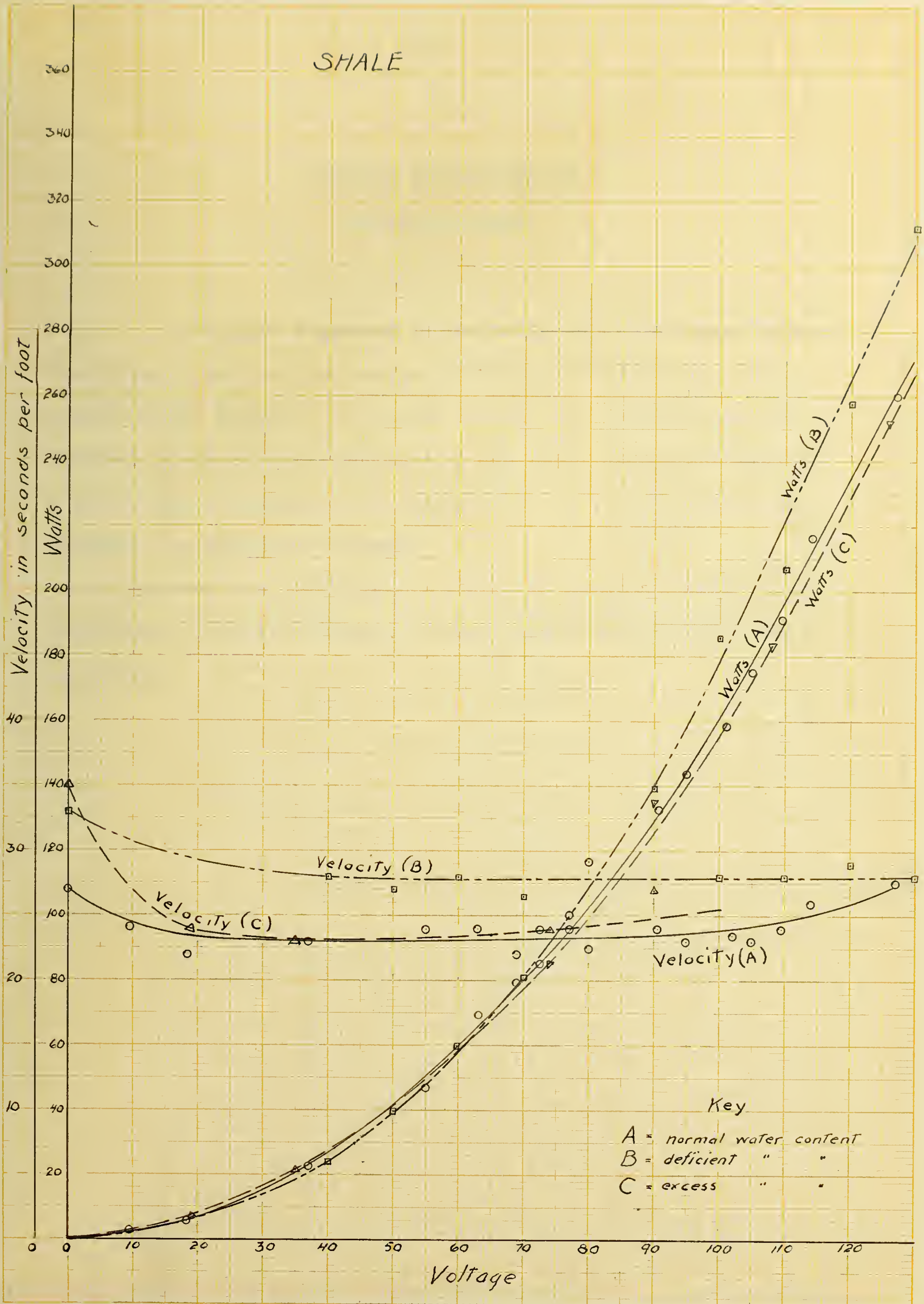

SHALE
Velocity in seconds per foot
Watts
Voltage
Watts (B)
Watts (A)
Watts (C)
Velocity (B)
Velocity (C)
Velocity (A)
Key
A = normal water content
B = deficient " "
C = excess " "

Summary of Results of Streator Shale

A slight increase of velocity was noted when using electrical lubrication instead of water lubrication. With a normal water content 90 to 100 volts were required to get perfect lubrication. Decreasing the water content increased the voltage necessary, and increasing the water content decreased the required voltage.

This was the only one of the three clays in which such a definite relation between voltage and water content could be noted.

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No.2 Fire-clay -D-

Volt.	Amp.	Watts	Vel. sec./foot	% water	Remarks
0	0	0	29.0	17.63	Corners slightly torn, surface good.
10	.35	3.5		17.95	Corners good, surface perfect.
15	.54	8.1		17.80	Corners good, surface perfect.
20	.78	15.6		18.08	Corners good, Striations appear.
30	1.08	32.4		17.42	and with increasing voltage the corners begin to show welds and the surface has increasing striations.
40	1.44	57.6		17.65	
50	1.83	91.5		17.07	
60	2.18	130.80		17.90	
70	2.52	176.4		17.64	
80	2.80	224.0		17.26	
90	3.22	289.0		17.42	
100	3.61	361.0		16.80	
				17.60	

Results

No.2 Fire-clay -D-

Sample D was pugged to obtain a water content averaging 17.60 %. This was below the amount normally used.

No current-	Only a slight tearing of the corners was noted, while the surface was judged good. A fair value of the velocity of the issuing column could not be obtained, due to the fluctuations in the power supplied.
10 to 15 volts-	An entirely satisfactory column was obtained within these limits. The velocity, however, was low, and fluctuated for the reasons given above.
15 to 100 volts-	The appearance of excess lubrication defects were noted immediately upon exceeding the 15 volt limit. The welded corners and the surface striations increased markedly with increase of voltage. The velocity still fluctuated as above.

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No.2 Fire-clay -E-

Volt.	Amp.	Watts	Vel sec/ft.	% water	Remarks
0	0	0	26.0	20.71	Corners slightly torn, surface good.
10	.28	2.83	23.5	19.90	Corners perfect, surface perfect.
15	.45	6.75	24.0	19.50	Corners perfect, surface perfect.
20	.57	11.50	23.5	19.81	Corners perfect, surface perfect.
30	1.00	30.00	23.5	19.92	Corners good, striations appear.
40	1.20	48.00	23.0	20.25	Corners good, striations slight.
60	1.70	102.00	23.5	20.10	Corners good, striations worse.
80	2.35	188.00	22.0	20.20	Corners good, striations thicker.
100	3.00	300.00	25.0	19.82	Corners fair, striations bad.
120	3.55	426.00	23.0	19.84	Corners fair, striations very bad.
				20.03	

No.2 Fire-clay -E-

A normal plasticity was obtained by pugging the sample to 20.0 % average water content.

No current- Slight tearing at the corners, but good surface was noted. A comparatively high velocity was obtained.

10 to 20 volts- A perfect column was obtained between these limits, and a slight increase of velocity accompanied.

30 to 120 volts- The corners showed very slight tendency to weld with increasing voltages, while the surface striations increased markedly, thus indicating excess lubrication. The velocity of the clay column remained practically constant.

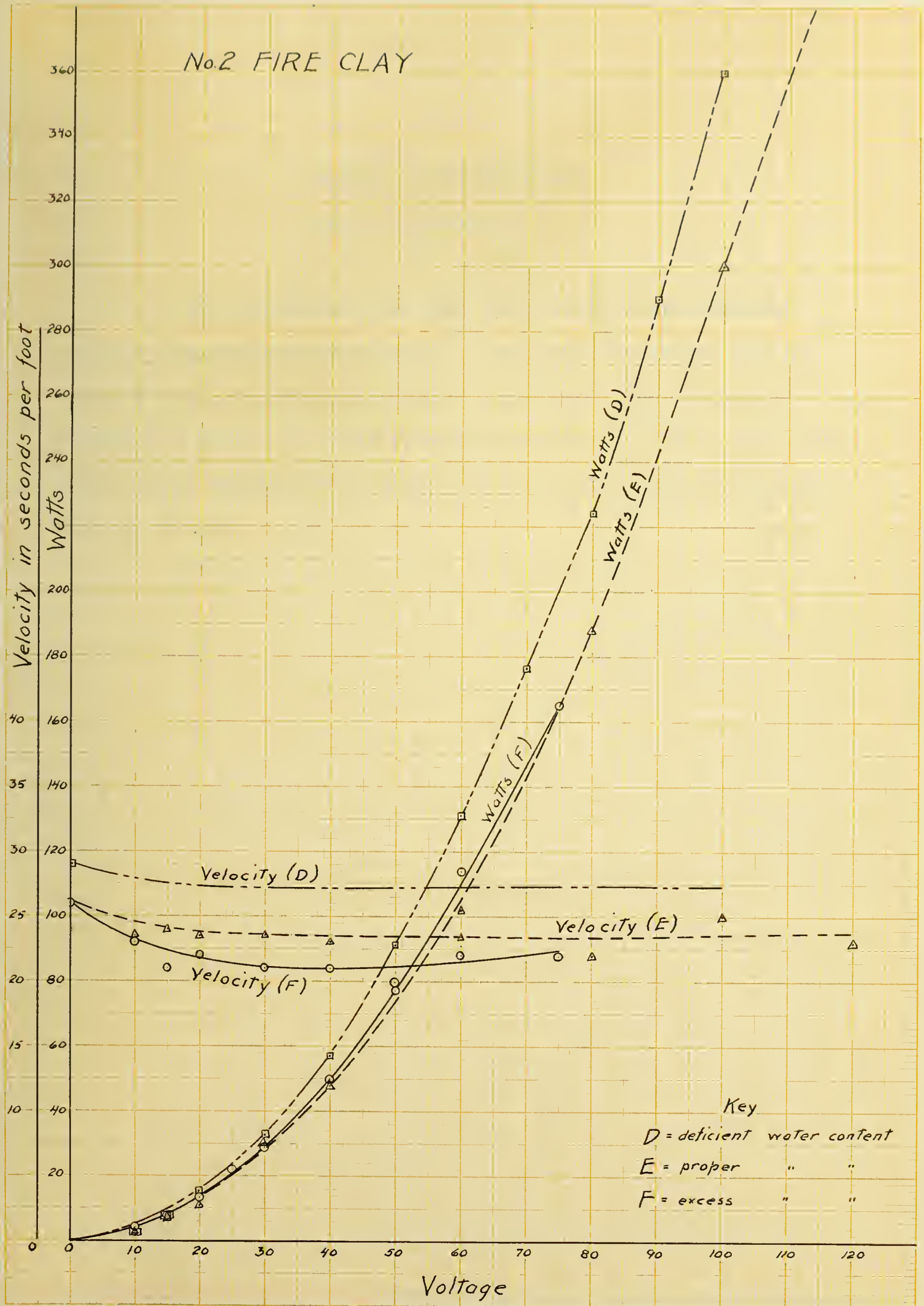
No.2 Fire-clay -F-

Volt	Amp	Watts	Vel. sec/foot	% water	Remarks
0	0	0	26.0	23.69	Corners badly torn, surface fair.
10	.39	3.9	23.0	23.51	Corners ruffled, surface good.
15	.50	7.5	21.0	22.20	Corners good, surface perfect.
20	.65	13.0	22.0	23.78	Corners perfect, surface perfect.
25	.88	22.0			Corners good, striations appear.
30	.95	28.5	21.0	23.92	Corners fair, striations stronger.
40	1.25	50.0	21.0	22.89	Corners fair, more striations.
50	1.55	77.5	20.0	23.11	Corners fair, striations worse.
60	1.90	114.0	22.0	22.87	Corners slightly ruffld. striations still worse.
75	2.20	165.0	22.0	22.30	Slight ruffling, striations bad.
			23.03		

No.2 Fire-clay -F-

Sample F was pugged to give an excess water content, the average being 23.03 % water.

No current.	Marked ruffling of the corners was noted, together with a slightly rough surface. The velocity was comparatively high.
10 volts-	The tearing tendency decreased considerably and the surface improved. There was a slight increase of velocity.
10 to 20 volts-	A practically perfect column was obtained between these limits. The velocity of the column was somewhat increased.
25 to 75 volts-	With increasing voltage there was a slight tearing at the corners, while the striations appeared immediately and increased noticeably. The velocity remained about constant.
Water lubrication-	At 5 pounds water pressure a perfect column issued at the rate of 28 seconds to the foot.


No.2 FIRE CLAY
Velocity in seconds per foot
Watts
Watts (D)
Watts (E)
Watts (F)
Velocity (D)
Velocity (E)
Velocity (F)
Voltage
Key
D = deficient water content
E = proper " "
F = excess " "

Summary of Results of
No.2 Fire-clay.

The electrical process gave considerably higher velocity than water lubrication. Varying the water content from 17 % to 23 % did not change materially the current required for obtaining a perfect clay column. Within the above noted water content percentages the voltage required is only from 10 to 20.

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Surface Clay -G-

Volt	Amp.	Watts	Vel. sec/foot	% water	Remarks
0	0	0	34.0	25.47	Corners ruffled, surface good.
10	.44	4.40	28.5	23.75	Corners perfect, surface perfect.
15	.65	9.75	26.0	23.89	Corners ruffle slightly surface perfect.
20	.80	16.00	24.0	23.94	Corners start welding, surface perfect.
25	1.05	26.25	25.0	23.82	Corners welding, striations appear.
30	1.30	39.00	27.0	24.34	Pronounced welding, striations thicker.
35	1.50	52.50	25.0	23.56	More welding, striations worse.
40	1.65	66.00	26.0	24.29	Worse welding, striations worse.
50	2.00	100.00	26.0	23.31	Bad welding. striations bad.
				24.04	

Results

Surface Clay -G-

To obtain a normal working plasticity 24.0 % water was used in pugging this sample.

No current-	A good surface and slight ruffling at the corners was noted. Low velocity was obtained.
10 volts-	A perfect column was obtained, but there was only a slight increase in the velocity.
15 to 50 volts-	With increase of voltage the characteristic welding of the corners, as seen with excess water lubrication, was noted. A marked increase of surface striations accompanied the increase of voltage. The velocity was low and remained practically constant.
Water lubrication-	With slight water lubrication a perfect column was obtained, which had an average velocity practically the same as with the electrical process.

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Surface Clay -H-

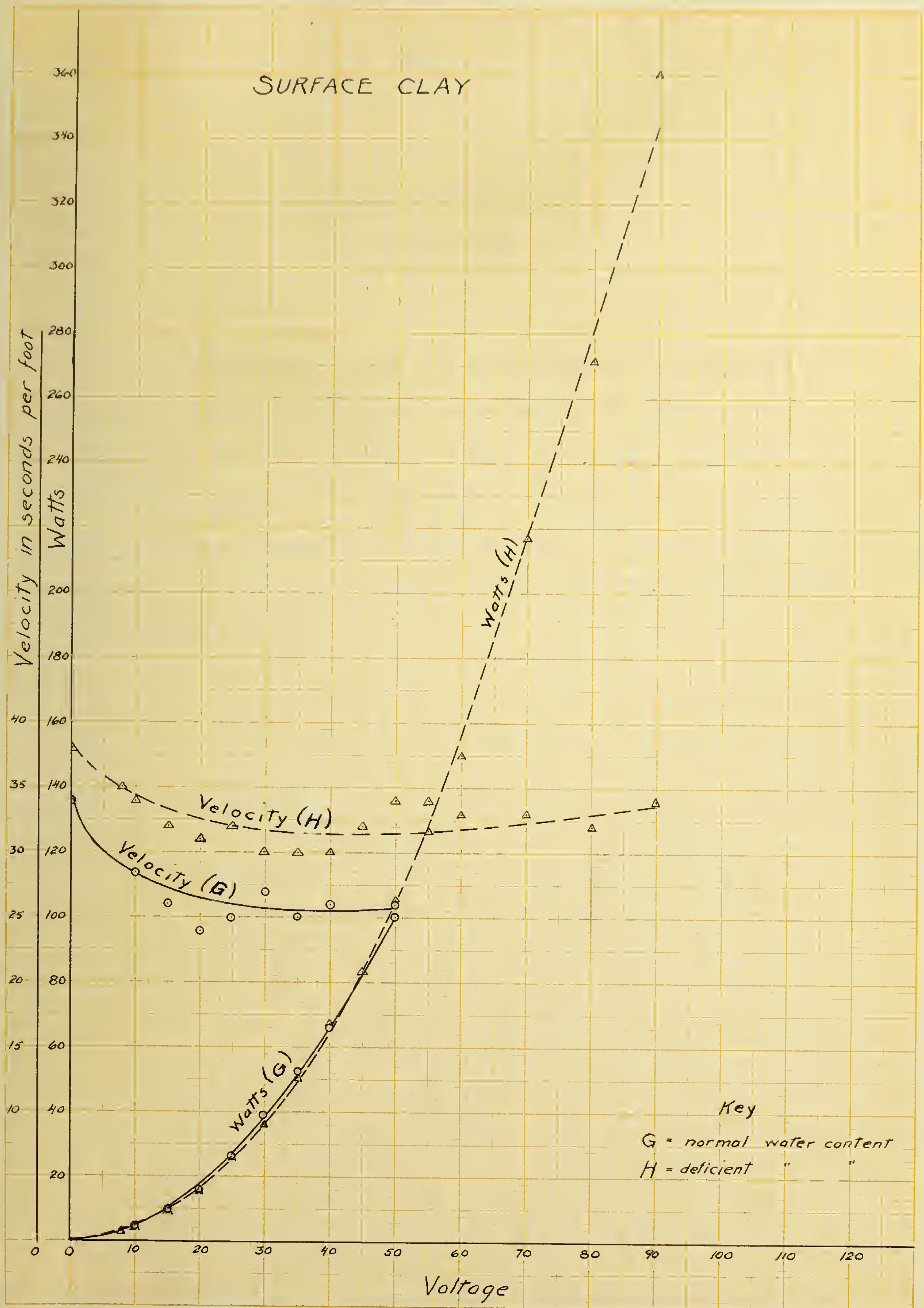
Volt.	Amp.	Watts	Vel. sec/foot	% water	Remarks
0	0	0	38	20.24	Extremely ruffled, surface poor.
8	.35	2.80	35	20.16	Corners ruffled, surface fair.
10	.50	5.00	34	21.30	Corners ruffled, surface fair.
15	.70	10.50	32	19.45	Slight welding, surface good.
20	.85	17.00	31	22.05	More welding, striations appear.
25	1.10	27.50	32	21.55	More welding, striations increasing.
30	1.12	36.00	30	21.24	Ruffling and welding, striations worse.
35	1.45	50.75	30	21.60	Corners weld badly, striations bad.
40	1.67	66.80	30	21.27	
45	1.85	83.25	32	20.80	Welding gets worse and the striations increase with the increasing voltage.
50	2.10	105.00	34	20.27	
55	2.30	126.00	34	20.43	
60	2.50	150.00	33	20.95	
70	3.10	217.00	33	20.75	
80	3.40	272.00	32	18.92	
90	4.00	360.00	34		
				20.73	

Surface Clay -H-

To obtain a sample deficient in plasticity only 20 % water was used in pugging.

No current-	Extreme ruffling at the corners and a poor surface was obtained, together with very low velocity.
8 to 15 volts-	A marked reduction of the corner ruffling together with an improvement of the surface was noted. The velocity of the column increased but slightly.
15 to 90 volts-	The nearest perfect results were obtained at 15 volts. With increasing voltage ruffling of the corners and welding was noted, as well as increasing surface striations, thus indicating excess lubrication. The velocity average was rather low.

No experiment was made with the clay containing an excess of water as the column would have required no lubrication whatever.



SURFACE CLAY
Velocity in seconds per foot
Watts
Voltage
Velocity (H)
Velocity (G)
Watts (H)
Watts (G)
Key
G = normal water content
H = deficient " "

Summary of Results of
Surface Clay

With normal water content there is no advantage in using the electrical process with regard to smoothness or velocity of the clay column. With a deficiency of water it seems probable that the electrical process will give very good results at about 10 volts, the velocity increasing very slightly. In the case of excess water content no lubrication is necessary at all.

VIII Conclusions

There is no doubt but that the electrical process is effective as a means of lubrication. Its successful application requires proper construction and wiring of the die and determination of the necessary voltage to be used for the given clay. The tests have shown definitely that the current required will vary with the kind of clay used.

Increasing the water content will, in general, reduce the required voltage, but more water in the clay means more work for the drier. On the other hand, a reduction in the water content will, generally, necessitate a higher voltage, which gives an increase in the expense for current. The current requirement of the process is, however, a comparatively small item in the cost of manufacture.

With the die insulation and wiring as in fig.8 and with the general set-up of the apparatus as shown in fig. 2 the electrical process will give excellent results and permit of easy and exact adjustments.